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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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INFORMATION CIRCULAR

GEOPHYSICAL ABSTRACTS

NO. 15

BY

FREDERICK W. LEE

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July, 1930.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

GEOPHYSICAL ABSTRACTS[1]

No. 15.

Compiled by Frederick W. Lee[2]

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1. GRAVITATIONAL METHODS

THE USE OF THE TORSION BALANCE IN THE INVESTIGATION OF GEOLOGICAL STRUCTURE

By W. F. P. McLintock and James Phemister

The Institution of Mining and Metallurgy, London. Transactions, vol. 38, 1929, pp. 299-303.

The form and distribution of the underground mass producing the gravitational disturbance and, hence, conclusions regarding the geological structure may be drawn by the determination by the torsion balance of the two following elements: (1) The gradient of gravity, and (2) the so-called horizontal directing tendency, H. D. T. or curvature vector. Eötvös' torsion balance enables these two elements of the gravitational field to be determined to an accuracy of 1 times 10^{-9} c.g.s. unit. According to the authors the most suitable areas for investigation by the Eötvös torsion balance are those characterized by: (1) A moderately flat surface topography (slopes not over 5°) and (2) a geological structure in which light and heavy rocks are brought into juxtaposition in such a way that the surface of separation between the light and heavy material is inclined to the horizontal.

Geological structures are divided by the authors, from the point of view of gravity surveying, into two classes: (1) Structures that can be determined by a straight line traverse across the strike (anticlines, synclines, dykes, faults, and lodes) and (2) structures that demand observations at a network of stations to determine even approximately their shape and dimensions (domes, basins, and intrusions whose length and breadth are comparable).

Three surveys completed by the Geological Survey with the Eötvös torsion balance are examined: (1) A gravitational survey over the Swynnerton Dyke; (2) a gravitational survey over the buried Kelvin Valley at Drumry, near Glasgow; and (3) localizing of a fault in carboniferous strata in the Edinburgh district.

In conclusion the authors say: "The results so far obtained by the Geological Survey with the Eötvös torsion balance have shown that the method is of considerable value in geological investigation. In suitable areas where the main features have already been determined by geological survey the balance may be of the greatest use in extending, detailing, and even correcting previous geological inferences. The Eötvös balance may also be used in prospecting for salt domes and large deposits of heavy minerals in areas where, by inference from the geology of adjacent areas, there is reasonable expectation of the presence of such structures and deposits."--W. Ayvazoglou.

FUNDAMENTAL PRINCIPLES OF THE GRAVITATIONAL METHOD OF PROSPECTING

By E. Lancaster-Jones

The Institution of Mining and Metallurgy, London, Transactions, vol. 38, 1929, pp. 304-308.

In this article the author reviews the conditions necessary for gravitational location of deposits and determines what prospects it has of successful utilization in the usual circumstances of occurrence of characteristic valuable deposits.

The most important factors upon which the gravitational "effects" depend are usually the following:

1. The density of the deposit relative to its surroundings.

2. The size of the deposit (the product of the relative density and size may be termed the "relative mass").

3. The nearest distance of approach to the deposit, which is usually the depth of the upper surface of the deposit below the surface of the earth.

For a very concentrated deposit of "relative mass" M metric tons and depth below the surface D meters, the extreme possible variation of the gravity gradient effect is approximately 115 $\frac{M}{D^3}$ Eötvös units, whence it will be apparent that for a practical extreme variation of 5 units, 23 M must be not less than D^3. Thus, for a depth of 1 meter M must exceed 1/23 metric ton. The following more dependable estimate is given:

For a depth of 1 foot the relative mass should exceed 5 pounds.
For a depth of 10 feet the relative mass should exceed 2 tons.
For a depth of 100 feet the relative mass should exceed 2,000 tons.
For a depth of 1,000 feet the relative mass should exceed 2,000,000 tons.

In a "bed" or "vein" formation the limiting relative masses must be increased.

As surface topography is an important source of disturbing effects, the gravity surveying is restricted to regions of comparatively low relief.

Other sources of disturbing effects are the local variations in the density of the upper portion of the ground in the neighborhood of the gravity observing stations and disturbing effects due to changes of density in the deeper strata which have no association with the valuable deposits sought.

The author summarizes the conditions favorable to the success of gravitational prospecting as follows:

1. The deposit sought should be of sufficient relative mass compared with its depth below the surface to give rise to variations in the Eötvös effects of at least 5 to 10 units.

2. The ground surface should be reasonably uniform and not interrupted by sudden upheavals or depressions, particularly in the neighborhood of the observing stations.

3. The "cover" should be homogeneous and preferably alluvial.

4. The subdrift topography should not be too irregular.

5. The strata should be evenly bedded, except where anomalies are associated with the deposit sought or are too deeply-seated to affect the observations.

In conclusion, Jones gives a few guiding factors relative to the cost of gravitational prospecting; for large-scale work in connection with extensive structures, a figure of £500 per month is regarded as a reasonable average cost for which about 100 stations could be expected. The cost of apparatus, which is £1,000 to £1,500 per instrument, must be added. In an "undeveloped" region of surveying, costs of transportation and maintenance of personnel and equipment must be taken into consideration.—W. Ayvazoglou.

GRAVITY EXPEDITION OF THE UNITED STATES NAVY

By F. A. Vening Meinesz

Nature, vol. 123, No. 3099, 1929, pp. 473-475.

The author describes the proceedings of the expedition carried out in the autumn of 1928 for determining gravity in the Gulf of Mexico and in the Carribean Sea. Observations were made on board a submarine. Two surface ships were added to the expedition. The total number of stations was 49. The pendulum apparatus was mounted in the central control room of the ship; the apparatus hung in gimbals which made it possible to work even if rolling or pitching was very great, say, 7°.

The apparatus used was constructed at the workshop of the Meteorological Institute at De Bilt (Holland). It consisted of a pendulum apparatus and a recording apparatus combined in one unit hung in gimbals. The pendulum apparatus contained three half-second pendulums swinging in the same plane; the pendulums were not recorded separately but combined in two pairs. The work and recording of the apparatus is described. Besides the pendulum observations a great number of soundings were taken.

The results of the gravity observations were provisionally computed during the voyage and at the same time the isostatic reductions of the stations were made at the Coast and Geodetic Survey. The final computations are now being made at the Naval Observatory in Washington.

The author makes the following statements concerning the provisional results. The Gulf of Mexico has shown a curious positive anomaly of about 60 millidynes over nearly its whole extent; a second result of importance was found north of Porto Rico. It shows great departure from isostatic equilibrium, which probably may be ascribed to stresses working in the earth's crust in connection with the formation of the deep. Over the deep is a great deficiency of gravity; before reduction it was more than 300 millidynes and after isostatic reduction, about 190 millidynes. North and south of the deep the anomaly after isostatic reduction is small; north of the deep it is slightly positive and south of it slightly negative.

The expedition must be considerod important for geodetic and geophysical science, especially if these researches are continued.—V. Ayvazoglou.

ZUR DREIACHSIGKEIT DER ERDFIGUR UND BEGRÜNDUNG DER LEHRE VON DER ISOSTASIE

(ON THE 3-AXIAL FORM OF THE EARTH'S FIGURE AND THE BASIS OF THE THEORY OF ISOSTASY)

By F. Hopfner

Physikalische Zeitschrift, vol. 31, No. 7, 1930, pp. 289-296.

Fifteen years ago F. R. Helmert raised again the question on the 3-axial form of the earth's figure; since that time this question has been constantly discussed in the geodetical and geophysical literature.

After Helmert, A. Berroth and W. Heiskanan calculated the figures for the 3-axial earth from the gravity measurements available in their time. Heiskanan obtained, after the reduction of the observations for isostasy, 345 meters as the difference A-C of the two semiaxes of the equator; the great axis intersects the equator at the points 18° and 198° east longitude of Greenwich; for the oblateness of the earth a figure equal to 1/294.3 was obtained along the eighteenth degree of longitude and a figure equal to 1/299.0 along the one hundred and ninety-eighth degree of longitude.

These results agree qualitatively with those obtained by Helmert and Berroth. They also have reduced the gravity measurements for isostasy. Both of them reduced the gravity measurement values according to the so-called free-air formula (Freiluftformel) for the surface of the sea level; that is, they reduced the values observed as if the attraction of masses (continents) rising above this surface did not contribute anything to the observed, respectively reduced gravity values.

This process can evidently be based on the physical assumption that the visible surplus of masses is equalized by the invisible deficiency of masses; therefore, the reduction according to the free-air formula remains, although primitive, an isostatic reduction proceeding.

The satisfactory conformity of the results obtained caused the 3-axial form of the earth's figure to be almost accepted in spite of the existing contradiction between this result and the theory of the equilibrium figures.

The 3-axial form of the earth has been doubted in recent years by M. Bossolasco, K. Mader, and R. Schwinner, who base their doubt on important objections.

Although the question has not been clarified yet and has even been extended recently by Mader into an interesting alternating question, there is already a possibility for a conclusive decision on the 3-axial form of the earth figure as accepted by Helmert, Berroth, and Heiskanen, if the decision is based on Bruns' mathematic-physical theory of the figure of the earth.—Author's abstract translated by W. Ayvazoglou.

2. MAGNETIC METHODS

THE MAGNETIC METHOD OF PROSPECTING

By Captain H. Shaw

The Institution of Mining and Metallurgy, London, Transactions, vol. 38, 1929, pp. 286-298.

After having mentioned a few historical data on the first magnetic observations and after a brief explanation of the principles of the work with a magnetic needle, Shaw discusses the magnetic method of prospecting under the following headings:

Measurements. Determination of the earth's magnetic field by measurin the declination, inclination, and intensity. Preferability for practical reason of measuring the vertical and horizontal components of the earth's magnetic fiel Instruments (magnetic variometers) by which these components may be determined with an accuracy between 5 gamma and 10 gamma.

Magnetic properties of rocks and minerals. Paramagnetic and diamagnetic bodies.

Permeability and Susceptibility. Explanation of these properties. A table showing the magnetic susceptibility and permeability of a number of rocks and minerals is given.

Local anomalies. Local and regional disturbances. Location of hidden tectonic structures such as anticlines, synclines, faults, monoclines, etc.

Results of typical surveys. Maps and explanations of the following typical examples are given: (1) Variation of the vertical component over a portion of the Kursk anomaly in Russia; (2) variation of the horizontal component over a deposit of serpentine; (3) horizontal and vertical intensity curves and total disturbance vectors over a magnetite deposit near Berggiesshübel; (4) variation of the vertical component obtained by Hoiland over the salt deposits at Lüneburg; and (5) horizontal and vertical intensity along a traverse across the Panhandle Arch.

Limitations. The development of the magnetic method for the location of weak anomalies requires a still further increase in the reliability and the accuracy of measurement of field instruments. By careful handling and under favorable conditions the author considers work with an accuracy of ± 5 gamma possible, but in general the mean error will be nearer ± 10 to ± 15 gamma.

Interpretation. Difficulties of the interpretation of magnetic irregularities are discussed and the necessity of borings for a complete interpretation of the results is pointed out.

Field operations. In prospecting for metalliferous minerals the magnetic method is considered by the author as the most rapid and least expensive of all the geophysical methods because it may be employed in hilly country, on soft swampy ground, or even in densely wooded areas. The time required for the occupation of each station with a modern instrument is estimated as 15 to 20 minutes, and the operating costs in a country which is not too densely wooded and which does not present transport difficulties ranges from £120 to £150 per month.--W. Ayvazoglou.

MAGNETIC DECLINATIONS AS ESTABLISHED AT THE OBSERVATORY OF STARA DALA DURING 1927-1928.

By V. Laska

Institut Géophysique National Tchécoslovaque, Bulletin Magnetique, vol. 1, No. 1, 1929, 24 pp.

This is the first number of the new periodical "Bulletin Magnetique," issued by the Institute. The purpose of the magazine is to give detailed magnetic data obtained by observations made in the observatories of the Republic. In this first number the director of the Institut, Prof. Dr. V. Laska, gives data of magnetic declinations established at the observatory of Stara Dala during 1927-1928. The position of this observatory is as follows: Latitude, 47° 52.5' N; longitude, 18° 11.4' E.--W. Ayvazoglou.

MAGNETIC DECLINATIONS IN BOHEMIA FOR THE EPOCH 1925.5

By Fr. Cechura

Rozpravy II, Tridy Ceske Akademie, vol. 39, No. 6, 1929, pp. 1-23.

In this article the author represents the results of the measurements of magnetic declinations (published in the same magazine, vol. 36, No. 35, 1927) in a map of isogons and in the form of empiric formulas of values of declination.

At the end of the article relations between the isogons and isonomals and between the geology and tectonic of the region of Bohemia are examined.— W. Ayvazoglou.

MAGNETIC DECLINATION IN MORAVIA-SILESIA REDUCED TO EPOCH OF 1925.5

By Fr. Cechura

Rozpravy II, Tridy Ceske Akademie, vol. 39, No. 53, 1929, pp. 1-30.

In this article the author publishes values of magnetic declinations obtained by a magnetic survey in Moravia and Silesia in 1928 for 41 stations. All these values were reduced to the epoch of 1925 to 1926 in conformity with the results of the previous work.

This article is completed by a table containing the elements necessary for making these reductions and for obtaining a general view on the magnetic fiel in Moravia and Silesia. These two countries, being situated between the Bohemian and Carpathian mountains, occupy a territory which is disturbed not only from the viewpoint of tectonic but also with relation to the magnetic field.—W. Ayvazoglo

3. SEISMIC METHODS

Seismic Methods

By A. O. Rankine

The Institution of Mining and Metallurgy, London, Transactions, vol. 38, 1929, pp. 309-322.

The question to be answered in this article is "How does a seismograph, by recording the times of arrival of the disturbances transmitted to it through the earth from an explosion, make it possible to estimate the depths and shape of the interfaces between strata of different materials?"

The fundamental requirement as regards the physical properties of the media above and below the interface which it is desired to locate by the seismic method is that the velocity of longitudinal disturbances must be less above the interface than below it.

A simple case, namely, a horizontal interface below the earth's surface at a depth h is examined and it is shown how this depth h can be calculated. The structure chosen for this calculation is the simplest possible one. It emphasizes, however, the fundamental principle upon which the seismic method is based, that is, the elucidation of underground structure by examination and interpretation of the time-graphs of "initial" disturbances received by seismographs and, more particularly, the discontinuities shown by these curves. More complicated cases arise, of course, in practice. The interface may be sloping instead of horizontal; it may not be plane, or it may have abrupt changes of directions, as in faults; and there may be more than two superposed strata. These complications introduce new unknown variables besides the depth, whose effects can be worked out thooretically. To deal with these additional features in practice it is necessary to increase the observation points and to change both the position of the explosion point and the direction of the observation line.

A series of diagrams, prepared by the author, illustrates the procedure. The diagrams represent:

1. The way in which the range for time equality increases with the depth of a horizontal interface; the two distances are proportional one to another.

2. The effect on the time-distance graph of changes in the ratio of the velocities below and above the interface.

3. The two next figures show that a sloping interface may give a graph identical with a horizontal one of a different velocity ratio.

4. The same fact is indicated in the two next figures in which the firing point is altered and the direction of observation reversed.

5. Two following figures exhibit the effect of pitch of the interface, the first showing that when the slope downwards becomes greater the break in the graph becomes less marked and more remote from the origin and the second demonstrating the possibility of a negative slope in the second branch of the graph corresponding to an apparently negative surface velocity.

6. The following three diagrams illustrate respectively the effects to be expected over a vertical fault and interface which dips abruptly but gently and a symmetrical anticline with flanks making a small angle with the horizontal.

7. The last diagram shows the calculated results for three strata separated by horizontal interfaces.

In conclusion Rankine points out that the chief advantage of the seismic method over the gravity method is the relative rapidity with which both field observations and calculations can be obtained; therefore, the seismograph should be regarded as the pioneer, to be followed, if desirable and possible, by the torsion balance to secure more exact information.—W. Ayvazoglou.

PHYSICS IN RELATION TO OIL FINDING

By A. O. Rankine

Nature, vol. 123, Nos. 3105 and 3106, 1929, pp. 684-686 and 718-720.

After a few introductory words on the task and possibilities of geophysical prospecting in general, Rankine gives an account of the seismic method of locating structures likely to be oil-bearing. This method can be applied even in rough country where gravity measurements are too much distorted by surface effects to give reliable indications of underground conditions. It depends not only on the relative densities but also on the relative elasticities of the rocks encountered or, what amounts to the same thing, the speeds of propagation of longitudinal mechanical disturbances in these media. These velocities range from about 5,300 meters per second for salt to about 2,000 meters per second for clay and sand overlying the dome.

One may perhaps digress for a moment to consider the possibility of using direct reflection from a clay-salt interface as a means of determining its depth. If a device similar to the depth-sounding machine, which has been successful at sea, could be used its great advantage would be that the measurement of the time taken for the sound to go down to the interface and return by normal reflection would enable the local depth to be estimated. The method proved unsuccessful in practice, however, because of the enormous damping of vibrations of audible frequency in the upper layers of the earth.

Thus, great disturbances of the earth's surface, generally in the nature of explosions, are necessary to penetrate effectively to the depths at which oil-bearing structures are frequently found. Therefore, a seismograph which will record vibrations of low inaudible frequency is preferable to the microphone on account of the smaller damping of such vibrations.

Using an explosion involves a difficulty on account of the appreciable time the consequent disturbance of the earth lasts. The solution to this difficulty lies in the existence in practice of another disturbance associated with the lower (higher velocity) medium but distinct from the reflected disturbance, which may, at a sufficient distance from the explosion, reach the seismograph first. Although small, the time of arrival of this disturbance can be readily recognized as it makes its record on the seismograph before the latter becomes violently disturbed by the direct waves.

The author discusses a simple case of two superposed horizontal strata in which the velocities of compressional waves are V_1 and V_2, the latter corresponding to the lower medium and being greater than V_1. If an explosion is caused at a certain point, three distinct disturbances reach the seismograph. One goes direct to the seismograph; another is reflected from the lower medium and arrives later, as its path is longer; and the remaining disturbance arrives at the seismograph at a time corresponding to the equivalent path from the point of explosion to the lower medium at the critical angle, $\theta_{c}=\sin^{-1}\frac{V_1}{V_2}$, then along the junction of the strata, traveling finally at the same critical angle up to the instrument. As V_2 (the velocity in the lower stratum) is the higher, it is evident that if the distance from explosion to instrument is great enough the total time occupied in transmission may be equal to or less than that for the direct path. If so, its small effect will be recognizable on the seismograph in spite of the large disturbance which follows afterwards. If a time graph is plotted, with the intervals between the instant of explosion and that of the initial disturbance of the seismograph as ordinates and the distances between explosion and seismograph as abscissae, it will display a break where the times of arrival of direct and indirect disturbances are equal. Actually, the distance x for time equality is related to the depth of interface by the relation $\frac{h}{x} = \frac{1-\sin\theta_c}{2\cos\theta_c}$.

Moreover, the slope which corresponds to the direct disturbance is proportional to $\frac{1}{V_1}$, while the slope which relates to the indirect disturbance is proportional to $\frac{1}{V_2}$. Thus, $\sin\theta_c = \frac{V_1}{V_2}$. Hence θ_c can be determined and its insertion in the above equation, with the value of x, read from the graph, enables the depth h of the interface to be calculated. Owing to its magnitude it is possible to recognize on the seismograms the arrival of the direct disturbance even when it reaches the seismograph after the indirect disturbance.

In all cases the procedure has to consist of the assumption of various possible underground structures until one is found which, by calculation, agrees with the time graphs actually obtained.

For this purpose it is frequently necessary to multiply observations by changing the position of the explosion point and the direction of the line of observation. The accumulation of field data over various structures also obviously facilitates the recognition of similar structures in subsequent surveys. Where, as often happens, the salt domes or limestone anticlines are deeply buried, large charges must be exploded because of the long ranges that must be covered to reach and pass beyond the point of time equality — an essential condition if the depth is to be determined. Consequently, it is economical to multiply the number of seismographs rather than the explosions. For celerity of survey the seismographs must be readily portable and easily set up in their new positions.

A group of five seismographs obtained with Mintrop seismographs over a salt dome is given.—W. Ayvazoglou.

LIST OF EARTHQUAKES IN THE BOHEMIAN MASSIF TO THE YEAR OF 1896 (IN BOHEMIAN)

By Em. Michal

Institut Geophysique National Tchecoslovaque, Bulletin Sismique, vol. 2, No. 1, 1928, 15 pp.

The Institute of Geophysics in Czechoslovakia is preparing a series of studies of earthquakes which have occurred on the territory of the Republic. In this first part of the work Michal gives a complete list of earthquakes from 768 to 1896. Historical material as well as seismic maps will appear in the following issues.—W. Ayvazoglou.

4. ELECTRICAL METHODS

ELECTRICAL PROSPECTING FOR ORE AND OIL

By Hans Lundberg

Mining and Metallurgy, vol. 11, No. 280, 1930, pp. 210-212.

In this article Lundberg discusses the use of electrical methods with special reference to the prospecting for ore bodies and the mapping of geologic structure. As the success of electrical prospecting depends on the difference in conductivity between the ore and the country rock, which varies considerably in different places, the conductivity of the two should be considered and determined if possible. Methods of identifying noncommercial conductors are of great importance; therefore, it is not sufficient to confine the electrical work to a mere location of an electrical disturbance and leave the interpretation to the geologist or mining engineer, as he may find nothing but a valueless mineralization of conductive rock.

In discussing the depth which can be measured by electrical methods, Lundberg says that theoretically there is no limit to the depth at which the body may be detectable by assuming that all its dimensions increase proportionally with the depth but that, practically, the maximum depth at which reliable results can be expected is 200 to 300 feet. The one solution of the problem of obtaining greater depths is to get down deeper with the apparatus, a solution that may be reached by grounding electrodes in deep drill holes, working in underground drifts, etc.

The cost of electrical surveys, if compared with other methods of exploring, must be considered cheap and is, according to Lundberg's experience, about $6.00 per acre for the primary or reconnaissance survey.

The last paragraph of the article deals with "mapping subsurface structure." This has its main use in prospecting for oil and salt. By assuming the simplest case for electromagnetic structural work, the case with only one conducting bed and the other beds very poor conductors, determining the depth of the conducting bed is then sufficient to make a subsurface contour map of the bed. The depth that can be reached depends on conditions, but results from 1,500 feet were actually obtained by the survey work made by the author. In speaking of the cost of survey in most petroleum regions the author says that 10,000 acres can be prospected per month at a cost of about $0.75 per acre.— W. Ayvazoglou.

OBSERVED AND THEORETICAL ELECTROMAGNETIC MODEL RESPONSE OF CONDUCTING SPHERES

By L. B. Slichter

The American Institute of Mining and Metallurgical Engineers, Technical Publication No. 332, 1930, 19 pp.

After stating the principles of similitude which apply to electromagnetic modeling, the author gives charts showing the inductive response of conducting spheres as dependent on frequency, conductivity, and size. The shape of the curve, which relates intensity of response to frequency, is significant in indicating the advisability of low frequencies in the exploration for conducting bodies, when consistent with securing a large percentage of the ideally possible response. Comparisons of theoretical response and that observed with models are shown, and relationships with the subject of applied electromagnetic prospecting are indicated.—Author's abstract.

ELECTRICAL PROSPECTING

By A. Broughton Edge

The Institution of Mining and Metallurgy, London, Transactions, vol. 38, 1929, pp. 323-334.

A summary account of the working principles on which the more important geoelectrical methods of prospecting are based is given in this article. Their particular merits and limitations are discussed.

The following electrical methods are examined:

1. Resistivity methods. In particular the 4-electrode method of Searle and Winner, developed by the Carnegie Institution and others, is mentioned. The author draws the conclusion that the resistivity methods may be of more direct value in the investigation of water problems (depth of water table, salinity, etc.), thickness of superficial deposits (clays, laterites, etc.), and determination of the depth of a conductive body which has been located by some other method.

2. Equipotential methods. The distribution of current is mapped in a simple manner by tracing the equipotential lines by means of a light movable circuit consisting of a sensitive galvanometer and a pair of nonpolarizing electrodes or, in case of alternating current (about 500 cycles), of a telephone and amplifier and a pair of pointed steel rods.

3. Electromagnetic methods. In these methods, which constitute probably the most important group, single-phase alternating currents are either passed through the ground between earthed electrodes, as in the equipotential method, or are produced inductively by means of loops of insulated wire which may be placed on the ground in a horizontal position, thus producing vertical fields, or in vertical position, thus producing horizontal fields.

4. Spontaneous polarization method. This method depends on the fact that electrochemical differences of potential are generated naturally in certain types of ore bodies in which oxidation of the mineral is in progress. In this way a well-defined circulation of current is set up in the surrounding country and, by mapping its distribution at the surface, the position of the concealed ore may sometimes be determined.

In discussing practical limitations of the electrical prospecting methods the author expresses the opinion that there is no convincing evidence so far to suggest that any of these methods are effective in locating mineral at depths from the surface exceeding 500 feet. It is also understood that the useful application of the electrical methods, in their present state of development, is definitely restricted to certain classes of mineral deposits.

The following considerations are of major importance:

1. It is not practicable to conduct electrical prospecting operations except in districts where mineralization of known characteristics has already been proved at some point.

2. The nature of the ore minerals and the physical character of the ore, in so far as they affect the electrical conductivity of the ore bodies whic are to be located, are of primary importance.

3. The effectiveness of the methods is also determined to a great extent by the nature of the inclosing and overlying country rocks.

Under the heading field operations Edge says a few words regarding the general nature of the work in which he gives some idea of the scale and expense of those operations. As a rule a single prospecting unit will consist of two operators with field instruments and auxiliary equipment to the approximate value of £600. The traveling expenses and salaries of these men must be borne in mind, also several kinds of overhead charges. According to the author a thre months' field work by a single prospecting unit involves a total expenditure of from £2,500 to £3,000.

Interpretation and proving the results forms the last chapter of the article. In the opinion of the author the interpretation of results requires considerable skill and experience; in the majority of cases approximate determinations of the depth and extent of concealed conductors may sometimes be made with errors of not more than 10 per cent. In their present state of development all that can reasonably be claimed for the electrical methods is: (1) That they are able to locate conductive zones lying at depths up to a few hundred feet and (2) that the depth and horizontal extent of these conductors can sometimes be determined with considerable accuracy.--W. Ayvazoglou.

PROSPECTING BY THE SWEDISH GEOELECTRICAL METHODS

By Karl Sundberg

The Institution of Mining and Metallurgy, London, Transactions, vol. 38, 1929, pp. 335-354.

After a brief historical description of geoelectrical methods of prospecting Sundberg gives an outline of:

1. The principle of the geoelectrical method.

2. Electrical conductivity of rocks in oil districts and relation between configuration of waters and geological structure.

3. Practical results.

The case of one conducting layer is discussed and illustrated by figures. As several conducting layers below each other generally must be taken into consideration, the elimination of the influence of conducting beds close to the surface is important. The theoretical problem of calculating the magnetic field for any number of conducting beds above each other has been solved. The reverse problem of finding the configuration of several beds is more complicated, the complication being more serious the larger the number of beds to be taken into consideration.

Before giving practical results of geoelectrical prospecting Sundberg discusses briefly the factors that determine the electrical conductivity of rocks, with special reference to the question, fundamental for geoelectrical structure work, of whether or not an horizon of certain electrical conductivity parallels the geological structure. The electrical conductivity of the rocks, which are all more or less porous, the pores being partly or completely filled with water, oil, or gas, is determined by the following two factors:

1. Percentage volume $\underline{v}$ of water in the rock.

2. Specific resistance $\underline{r}$ of water in the pores.

In a table the average pore volume and water content for different rock types are given. Another table, given below, shows the magnitude of the specific resistance of different rocks established according to the present knowledge.

Specific Resistance (ohms per cubic centimeter)

Rock	Pores filled with surface or ground water	Pores filled with salt water
Limestone and sandstone	100,000 - 1,000,000	500 - 5,000
Sand and clay	40,000 - 400,000	200 - 2,000
Marl, "Loess"	2,000 - 20,000	20 - 200

The variation in electrical properties is thus large enough to make a large contrast possible between a certain bed as compared with any other. A geoelectrical survey is more likely to give good results the more pronounced this contrast is.

Sundberg states that only a few of the practical results can be given because most of his work has been carried out with the condition that the results shall not be published.

The results of geological and geoelectrical investigation of the Lanzendorf area close to Vienna are shown in the accompanying map. The geological and geoelectrical investigations were carried out independently by different persons but agroe very well, although the electrical results are apparently much more detailed than the geological. Two other figures show the example of a tectonic survey. The problem was to locate faults. Some of them were located, In the last figure the results from geoelectrical mapping of a dome, confirmed by a later drilling, are shown.—W. Ayvazoglou.

5. RADIOACTIVE METHODS

THE SENSITIVE SURFACE OF THE GEIGER TUBE ELECTRON COUNTER

By L. F. Curtiss

Bureau of Standards Journal of Research, vol. 4, No. 5, 1930, pp. 601-609.

Experiments with the new Geiger tube electron counter show that no preparation of the central wire electrode is necessary, which contradicts results reported by Geiger.

Such wires as bare copper, bare steel, lacquered steel, oxidized tungsten, and oxidized nichrome work satisfactorily. All of these wires cease to work when such gases as H_2S, SO_2, ethylene, or water vapor are admitted. This shows that at the pressure at which these counters work enough oxygen is absorbed to permit the counter to operate. When another gas with different absorptive properties is admitted the counter can no longer function.—Author's abstract.

EXPERIMENTAL INVESTIGATION OF THE ELECTRON COUNTER

By H. Geiger and W. Müller

Physikalische Zeitschrift, vol. 30, August, 1929, pp. 489-493.

The authors have already described an electron counter which may be used for the quantitative investigation of extremely weak radiations of either atomic or corpuscular nature. The apparatus consists simply of a metal tube with an axial fine wire whose surface is coated with a half-insulating skin. In consequence of this skin the potential on the wire may be raised so high that on the entry of even weak beta radiation the ionization by collision makes it easy to observe the incidence of the beta radiation with an instrument of normal sensitivity. The present series of experiments was made to test the working of the counter under various conditions.

It is shown that the number of secondary beta rays observed when weak gamma rays fall on the counter is practically constant as soon as the pressure increases to more than 5 cm. of mercury. Even at 1 mm. of pressure, however, a considerable fraction of the maximum number of particles is observed.

The effects of varying the type of gas (A, H_2, air, CO_2) and the diameter of the central wire are discussed. The number of observed impulses per minute over a considerable voltage range with a "good" wire remains constant (1,300 to 1,600 volts). Practical hints for the detection of "good" and "bad" fibres are given. The sensitivity of a counter along the length of its axis was investigated by using a narrow bundle of beta rays from RaD + E. The sensitivity remains constant over most of its length but drops near the insulators at the ends of the tube. Experiments with tubes of various materials (paraffin, Al, Fe, Ni, brass, Zn, lead) show only small variations except in the case of lead. The directional effects of the secondary beta rays produced by gamma rays may be easily demonstrated. For cosmic rays such asymmetry is not observed as would be expected if they are indeed corpuscular as suggested by Bothe and Kohlhörstor. Experimental evidence is marshalled to show that the counter records all of the beta rays falling on it. The paper contains much useful experimental information and should be consulted for details.—Reprinted from Science Abstracts, Sec. A., vol. 33, No. 387, 1930, p. 291.

NATURE OF COSMIC RAYS

By P. Auger and D. Skobelzyn

Comptes Rendus, vol. 189, July 1, 1929, pp. 55-57.

The suggestion put forward by Bothe and Kolhörster that cosmic rays are in reality not gamma rays but high-speed beta rays is shown to be inconsistent with the results of certain expansion chamber experiments.

These experiments show the immediate cause of the ionization produced to be high-speed beta rays, but the frequent occurrence (four times out of 27 "fruitful" expansions) of several high-speed beta ray tracks in one expansion, the tracks being near together and having almost the same directions, makes it almost certain that they arise in common from a ray of another character. Assuming the cosmic rays to be of gamma ray type and the high-speed beta rays to be Compton electrons produced by Compton scattering of the primary cosmic ray, the observed results are easily explained.—Reprinted from Science Abstracts, Sec. A., vol. 33, No. 385, 1930, p. 59.

7. UNCLASSIFIED METHODS

ECHO SOUNDING

By H. Maurer

Hydrographic Review, vol. 6, No. 2, 1929, pp. 21-28.

During the cruise of the German vessel Meteor in the Atlantic Ocean 67,000 soundings at 34,000 stations were taken. In this article Maurer brings up the question as to how they should be treated. In the experience of the Meteor the depths were frequently much greater than the echo distances. Out of 245 comparisons of depths of over 2,000 meters 56 cases gave a difference exceeding 100 meters, and the maximum difference amounted to 650 meters when the wire gave 4,840 meters depth. To calculate the true echo distance, the mean velocity of sound between the ship and the bottom must be known. It varies according to the temperature, salinity, and pressure (from 1,400 meters per second in cold fresh water to 1,620 meters per second at the bottom in the greatest depth). By means of the "Tables of the velocity of sound in pure water and sea-water for use in echo-sounding and sound-ranging," issued by the British Admiralty in 1927 under the number H. D. 282, it is possible to calculate the mean velocity in any column of water between the surface and the bottom at any place where the range of the temperature and salinity in the column is known.

On German charts the results of sonic sounding (over 200 meters) are entered as echo distances, all of which are deduced from one constant velocity (1,490 meters per second) on which all German echo-sounding machines are based. With reference to the Meteor's soundings, 7,000 stations have been inserted on the charts and the average horizontal distance between stations is 10 sea miles. The crude echo distances calculated on a single constant velocity are the most useful not only for the seaman but also for science as they can be corrected according to the most recent data available. Results of echo sounding given in the form of depths without indication of the velocity on which they are based are useless to accurate science.—W. Ayvazoglou.

GEOPHYSICS EDUCATION

By C. A. Heiland

Mining and Metallurgy, vol. 11, No. 281, 1930, pp. 250-251.

In this article Heiland discusses briefly the question of providing men well trained in geophysical prospecting. This subject is presented by the author in three ways: (1) The trade school idea, (2) the pure science idea, and (3) the engineering idea; the last being in his opinion the superior one.

The method of instruction adopted at the Colorado School of Mines is given. The men to be trained in geophysics are required to take almost all the work required of the geological engineer; they also take one course in geophysical mathematics and one course in advanced physics in their third year, two general geophysical courses, and at least two special geophysical courses in their last school year. To obtain a M.S. or Sc.D. degree with a major in geophysics, advanced courses in geology, physics, and mathematics should also be taken.—W. Ayvazoglou.

GEOPHYSICS

By W. H. Fordham

Journal of the Institution of Petroleum Technologists, vol. 18, No. 80, 1930, pp. 97-107.

Fordham gives a brief account of a series of articles showing the results of geophysical work during the last years. Instruments, theory, practical application, and results of gravimetrical, seismic, magnetic, and electric methods of prospecting are discussed.

To show the growth of geophysical work in the United States, Fordham gives some figures on the number of instruments used: (1) The first four torsion balances were imported into the States in 1922 and within two years, 1924 to 1926, their number increased to more than 100; (2) the number of seismic troops in the field in 1929 is given as 28; and (3) the number of magnetometers in use has increased to more than 300.

In conclusion Fordham summarizes the cost of surveying as given by several authors:

"Barton gives the cost of running a single torsion balance at $1,200 a month, during which 50 stations should be done. With the gradiometer a very much larger number of stations could be completed per month.

"Barton says that the cost of operating a standard seismic troop in the Gulf Coast salt dome area is reported to average between $15,000 and $20,000 a month.

"Spraragen estimates that the salaries and running expenses of a 3-instrument magnetic survey party amounts to $1,700 a month, 75 stations a day being done on the average, in 5 days each week. This estimation does not include depreciation of instruments.

"Edge considers that three months' field work with an electrical unit, consisting of two operators and equipment, would probably involve a total expenditure of £ 2,500 to £3,000."

A list of articles used by the author as references is added.—W.Ayvazoglou.

GEOPHYSICAL SURVEYING

By W. H. Fordham

Journal of the Institution of Petroleum Technologists, vol. 15, No. 72, 1929, pp. 35-66.

After a brief explanation of the expression "geophysical surveying" which is formulated as "the application of physical measurements made, in most cases, on the surface of the earth to the discovery and mapping of hidden geological structures and mineral deposits," the author explains the nature and the use of geophysical instruments in the gravimetric, seismic, magnetic, and electric methods of prospecting. The value of geophysics in the search for oil by these methods and the cost of surveying are discussed under special headings. In conclusion the author says:

"From the results described in the present paper it is evident that geophysical methods are already proving a valuable aid to the geologist; and it is reasonable to look forward to a time when the subject will be an important branch of geology.

"The limitations both of the methods and of interpreters are becoming better understood, at any rate in the United States."

On the question of interpretation Fordham refers to the following statement of Dr. Barton, concerning especially the gravimetric method:

"To get the most out of torsion balance surveys, the interpreter should be a good mathematician and geologist, should have had a chance to study the mathematics of interpretation, and should have had a broad practical experience with the method. There are very few men who have had sufficient opportunity to study the mathematics of the interpretation and who have had sufficiently broad experience to qualify as competent interpreters. It is and will be easy to get men who are able and competent observers and who possess a fair but superficial knowledge of interpretation. A great danger to the full realization of the possibilities of the method is that the company employing such a man as an interpreter may fail to recognize his limitations. Another danger is that a company that realizes the necessity of training itself and its interpreter by theoretical study and practical experience will become overimpatient and overenthusiastic and may force him to practical utilization of the method before he is competent to use it. A company that has had much experience with geology has become educated to the fact that geology is not a 'sure-shot' panacea for finding oil and is satisfied to allow geology a considerable number of failures if it turns up a fair number of successes; but there is a good possibility that the same company will condemn the torsion balance after a very few failures, without regard to whether the failures were due to the method or to the incompetence or inexperience of the interpreter."

Another obstacle to the wider application of geophysics, mentioned by the author, is the lack of knowledge of results already obtained; thus, the establishment of a Geophysical Institute that would keep a record of the work taking place throughout the world and insure the necessary liaison between physicists, instrument makers, and geologists would facilitate the development of geophysical methods on sound lines.

A bibliography of articles on geophysical methods of prospecting is added.—W. Ayvazoglou.

8. GEOLOGY

THE RECENT ACTIVITIES OF THE GEOLOGICAL COMMITTEE OF THE U. S. S. R.

By D. Mushketov

Economic Geology, vol. 24, No. 8, 1929, pp. 860-866.

A brief account of the work of the Geological Committee in the U. S. S. R. is given. According to the author the number of field expeditions reached 628 as compared with 389 for the previous year (1929).

Systematic study of the geological structure has been conducted over most parts of the Union.

Field study of the following mineral deposits has been carried on:

Iron.- Diamond drilling in Krivoy Rog, 802 meters deep, increased the total reserved to 61,000,000 tons. A magnetometer survey disclosed many new anomalies. The reserves established in the region of Kertch amount to 2,002,000,000 tons.

Manganese.- Preliminary reserves in the Nicopol region were estimated at 83,000,000 tons; those in the Achinsk region, Siberia, at 1,000,000 tons.

Tungsten.- Deposits containing several hundred tons have been revealed on Sherlov Mountain.

Nickel.- Tulenevsky deposit (Ural) revealed an additional reserve of 3 per cent ore. A new deposit, that of Krestinski, delimited an area of about 8,000 sq. km. with ore averaging 3 per cent.

Copper.- New ore bodies have been discovered in the Arshinsk deposit. Porphyry-copper deposits have been discovered in the Kazakstan Republic, Central Asia.

Lead.- A new fluorite-barite lode with a reserve of 20,000 tons of lead has been discovered in the Uzbekistan Republic, Central Asia.

Tin.- A number of new deposits have been discovered in Transbaikalia.

Gold and Platinum.- The discovery of gold placers of industrial value in the Yakutian Republic along the Ur-Kuma River and in the Cheremnaya River basin is mentioned. A new deposit containing 12 lodes has been discovered in the Saralinsk region, Siberia. A part of these discoveries is due to electrical methods of prospecting.

Asbestos.- An industrial quality of asbestos has been proved in two deposits, Gondurikhinski in the Ural and Aspaganski in Siboria.

Sulphur.- Preliminary reserves of 30 per cent sulphur ore amounting to 375,000 tons have been defined in Turkmenistan.

Potassium.- The probable total reserves in the Ural province potassium salt areas are estimated to be 900,000,000 tons.

Coal.- A new deposit of about 9,000,000 tons has been revealed in the Moscow basin. The reserves of minable coking coal at Tkvarcheli (Abkhasian Republic) amount to 110,000,000 tons. Several prospecting parties worked in the Far East.

Oil.- Oil investigations consisted of a systematic study of structures in oil-bearing regions and of prospecting for new deposits.

Prospecting.- Attention is called to the special geological work related to prospecting which consisted of drilling and mining work as well as the use of geophysical methods. Seventy-three parties were engaged in drilling, 52 parties carried on the mining field work, and 32 parties used geophysical methods.

Topographic work.- The areas covered by instrumental work were 15,795 sq. km. and by partly instrumental survey, 16,278 sq. km.—W. Ayvazoglou.

NEW BOOKS

Bayley Willis and Robin Willis. Geological structures. 2d ed., revised and enlarged. 518 pp. 163 figs., McGraw-Hill Book Co., New York, 1929 (October), price, $4.00.

Greenly, Edward and Williams, Howel. Methods in Geological Surveying. 420 pp., 81 text figures, 3 plates, and a list of bibliography. Thomas Murby and Co., London (D. Van Nostrand Co., New York), 1930, price, 17s. bound.

Jeffreys, Harold, Dr. The Earth: Its Origin, History, and Physical Constitution. 2d ed. Pp. lx and 346. Cambridge, at the University Press, 1929, 20s. net.

Milner, Henry B. Sedimentary Petrography (with special reference to petrographic methods of correlation of strata and to subsurface oil geology). 2d (revised and complete) ed. Thomas Murby and Co., I, Fleet Lane, E. C. 4, London. D. Van Nostrand Co., 8 Warren St., New York (1929), 502 pp., illustrated, cloth, 5 1/2 by 7 1/2 inches. Price, $8.00.

Pitman's Technical Dictionary of Engineering and Industrial Science in Seven Languages -- English, French, Spanish, Italian, Portuguese, Russian, and German. Compiled by Ernest Slater, vol. I: A - Dec. pp. X and 581. Vol. 2: Dec - Kau. pp. III and 582 - 1155. Vol. 3: Lab - RiC. pp. III and 1156 - 1727. Vol. 4: Rib-Zon. pp. III and 1728 - 2211. London. Sir Isaac Pitman and Sons, Ltd., 1928-1929. Four volumes, £8, 8s. net.

Section de Geodesie de l'Union Geodesique et Geophysique Internationale (The Section of Geodesy of the International Union of Geodesy and Geophysics). Special Publication No. 2: Tables de l'Ellipsoide de Reference international adopte par l'Assemblee generale de Madrid le 7 Octobre, 1924, dans le systeme de la Division sexagesimale de la Circonference (Tables of an international ellipsoid of reference adopted by the general meeting in Madrid on October 7, 1924, for the system of the sexagesimal division of the circumference). Calculated by E. Hasse under the direction of General G. Perrier. Pp. 20 and 91. Paris, Union Geodesique et Geophysique Internationale, 1928.

Sineritz, J. G. Los Metodos Geofisicos de Prospeccion (Geophysical Prospecting Methods). Boletin del Instituto Geologicode Espana (Madrid) Tome 10, Tercera Serie, 498 pp. 215 figures. (A French translation of the book is already in preparation).

Wein, W. and Harms, F. Handbuch der Experimentalphysik. Unter Mitarbeit von H. Lenz. Volume 25: Geophysic. Part I. Edited by G. Angenheister, pp. XIV and 699. Leipzig. Akademische Verlagsgesellschaft m.b.H., 1928. The first quarter (165 pages) of the book, by A. Defant, deals with the general dynamics and statics of the atmosphere apart from its tidal and thermal oscillations of which an excellent account (48 pages) is given by J. Bartels. W. Milch summarizes the optics of the atmosphere (44 pages and H. Benndorf, the electrical phenomena (128 pages) apart from the aurora, which is described by L. Vegard (94 pages) and the penetrating radiation (K. Büttner, 48 pages). Terrestrial magnetism (158 pages) is dealt with by G. Angenheister and J. Bartels. The book concludes with good indexes of subjects and authors.

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